https://doi.org/10.61308/NKHD6477

# Influence of the inter-row tillage on vegetative and productive performance of maize (*Zea mays* L.)

**Nesho Neshev*, Hristiyana Hristova, Mariyan Yanev, Anyo Mitkov**
Agricultural University – Plovdiv, Bulgaria
*E-mail: *n_neshev85@abv.bg*

**Citation:** Neshev, N., Hristova, H., Yanev, M., & Mitkov, A. (2025). Influence of the inter-row tillage on vegetative and productive performance of maize (*Zea mays* L.). *Bulgarian Journal of Crop Science, 62*(4) 3-8.

**Abstract:** The effect of the inter-row tillage on maize (hybrid "Blason Duo") growth, development and grain yield was under evaluation in a three-year study (2020, 2021 and 2022). The trial was performed by the long plots method on the experimental field of the Agricultural University of Plovdiv, Bulgaria. The study included the following variants: 1. Zero inter-row hoeing; 2. Single inter-row hoeing (in crop growth stage 3rd – 5th true leaf); 3. Double inter-row hoeing (in crop growth stages 3rd – 5th true leaf and 7th – 8th true leaf); 4. Triple inter-row hoeing (in crop growth stages 3rd – 5th true leaf, 7th – 8th true leaf, and 10th – 12th true leaf). All studied parameters as plant height, ear length and diameter, grain yield, absolute and hectoliter seed mass were influenced by the inter-row hoeing performed. The highest results for all studied indicators were obtained for variant 3. The application of the third inter-row hoeing (in variant 4) led to crop damage and it is not recommendable to be performed in practice.

**Keywords:** maize; inter-row hoeing; growth; yield

## INTRODUCTION

Maize is among the top produced crops worldwide with an annual production of more than one billion metric tons worth (Serna-Saldivar, 2023). It is a raw material for production of starch, vegetable oil, dextrin, liquid and medical glucose, alcohol, paper, fibers and other drugs. In Bulgaria there is a plenty of products produced by this cultural plant. Besides, the crop is crucial for the country as being the second most cultivated cereal in it after wheat (Tyutyundzhieva, 2010).

Weeds may largely affect maize's production systems throughout the world causing significant yield losses. Herbicides are widely used for weed control in maize production systems, but can pose serious environmental consequences (Mhlanga et al., 2016).

Weed hoeing could be of a great advantage when there are herbicide resistant weeds found in the crop field (Machleb et al., 2018).

The integration of non-chemical weed management approaches with herbicides not only increases weed control efficiency, but can overcome problems associated with over-reliance on herbicides alone (Ghosh et al., 2017).

Many authors report that in its early growing stages maize is quite sensitive to weed competition which draws attention to the fact that not only between but also within crop rows weed control needs to be effective (Gerhards et al., 2020). Inter-row tillage is an essential alternative for dealing with weeds in an ecological way which can be implemented in integrated weed management systems (Damian, 2011).

An experiment conducted by Kandil & Kordy (2013) implies that the most significant weeds reduction was accomplished both with two-times hand-hoeing and by the use of post-emergency herbicides combined with one hand hoeing. Additionally, the highest leaf area index as well as the greatest mean of biological yield were achieved by hand hoeing twice.

One paper discusses the role of hoeing and intercropping with *Mimosa caesalpiniifolia* (sabia) in order to control weeds in maize. The author declares that intercropping sabia is a possible way of managing weeds since there is no hoeing at all, but what decrease the weeds to a greater extend are two hoeings (20 and 40 days after sowing the maize). Again, the treatments involving hoeing show less weed growth. Moreover, hoeing twice is what obtain the highest yields for maize (Sampaio et al., 2015).

Researchers in Romania examine how mechanical hoeing, manual hoeing and a combination of both would affect the weed infestation in maize fields. The study give prominence to the need of reduction of weed number by applying the pointed methods due to the strong correlation between the weed number and the grain yield (Damian, 2011).

According to Van der Werf et al. (1991) the inter-row tillage can reduce the herbicide application in maize and my increase the available water and nitrogen in the soil.

The above cited literature gives information of the inter-row tillage as a good weed control method. The information of how the inter-row tillage is influencing the maize growth, development and productivity is very scarce and absent. Therefore, the aim of the current study was to evaluate the number of the inter-row tillage operations on maize development and productivity.

## MATERIALS AND METHODS

The trial was situated in the experimental field of the Agricultural University of Plovdiv, Bulgaria. The study was conducted by the long plots method in three subsequent vegetation seasons of maize - 2020, 2021, and 2022. The size of an experimental plot was 100 m$^2$. One harvesting plot consisted of six maize rows. According to Popova et al. (2012) the soil on the experimental field is classified as alluvium. Based on the international classification of FAO, it is defined as Mollic Fluvisols. The soil has average sandy-clay mechanical composition, low humus content and a weak-alkaline pH. The content of nitrogen is low, the phosphorus content varies from low to average, and the potassium content is high.

The grown maize hybrid was "Blason Duo". Characteristics of the maize hybrid "Blason Duo": FAO Group 450; tolerant to the herbicide cycloxidim; high-yielding hybrid forming ears low and uniformly (https://euralis.bg//43-es-blason-duo/).

The study included the following variants:

1. Zero inter-row hoeing;
2. Single inter-row hoeing (in crop growth stage 3$^{rd}$ – 5$^{th}$ true leaf);
3. Double inter-row hoeing (in crop growth stages 3$^{rd}$ – 5$^{th}$ true leaf and 7$^{th}$ – 8$^{th}$ true leaf);
4. Triple inter-row hoeing (in crop growth stages 3$^{rd}$ – 5$^{th}$ true leaf, 7$^{th}$ – 8$^{th}$ true leaf, and 10$^{th}$ – 12$^{th}$ true leaf).

The inter-row hoeing was performed with inter-row cultivator with duck foot share working organs, mounted on springs. The cultivator was attached to a tractor model "Belarus 1220".

The following parameters of maize were under evaluation:

- Plant height at the end of the vegetation (m);
- Ear length (cm);

The measurement of the plant height and the ear length were performed on three samples that consist of twenty plants and ears respectively (sixty plant samples total per variant).

- Maize grain yield (t ha$^{-1}$). The yields were determined by manually harvesting the middle two maize rows from each plot.
- Absolute seed mass (g). Three samples of the parameter were measured (Tonev et al., 2018).
- Hectoliter seed mass (kg). Three samples of the parameter were measured (Tonev et al., 2018).

Preceding crop of maize was winter wheat. On the whole experimental field combined fertilization with 250 kg ha$^{-1}$ with N:P:K (15:15:15), followed by deep ploughing was done. Before the maize sowing, disking on the depth of 15 cm and two times harrowing on 8 cm of depth as well as spring dressing with 250 kg ha$^{-1}$ $NH_4NO_3$ was also done.

To keep the experimental area free of grass and broadleaf weeds a combined application of Stratos Ultra (100 g/L cycloxidim) – 2.00 L ha$^{-1}$ + Casper 55 WG (500 g/kg dicamba + 50 g/kg prosulfuron) – 0.30 kg ha$^{-1}$ in a tank mixture was applied. The volume of the spraying solution was 21 L ha$^{-1}$. During the research no insecticides and fungicides were applied.

The trial was conducted under irrigated conditions. For this purpose, drip irrigation system was established. The irrigation hoses were placed between the maize growth stage 5$^{th}$ – 7$^{th}$ true leaf. The hoses were removed before preforming the second and the third inter-row tillage operations of variants 3 and 4. The hoses were placed on the same places after performing the inter-row tillage for each treatment.

Statistical analysis of the obtained data was performed by using Duncan's multiple range test by the software SPSS 19. Statistical differences were considered proven at $p<0.05$.

## RESULTS AND DISCUSSIONS

On Figure 1 the data for the average monthly temperatures during the maize vegetation in the three experimental years is presented. According to the meteorological data, it can be assessed how climatic conditions affect the growth and development of the plants. The amount of precipitation is not shown because the plants were grown under irrigation conditions.

The average minimum and maximum air temperatures differed during the maize growing seasons. The air temperatures were suitable for the plants' growth and development. No extreme values affecting the crop were registered during the study.

Results of an experiment reveal that hoeing maize twice is a very successful practice. Indicators such as plant height, leaf area index, etc. were considerably increased (Saudy, 2013). On Table 1 is presented the obtained data concerning the plant height at the end of the vegetation. The highest results were found to be for treatment 3 (Double inter-row hoeing) – 2.77 m of height average for the period.

Inter-row cultivation is an effective mean to decrease the widespread use of herbicides in maize. However, it could significantly damage plant parts as roots whenever the cultivation is deep. In our study the application of the third inter-row hoeing (in variant 4) led to crop damage as plant lodging and breaking that was overcome by the most of the plants, but the energy used for

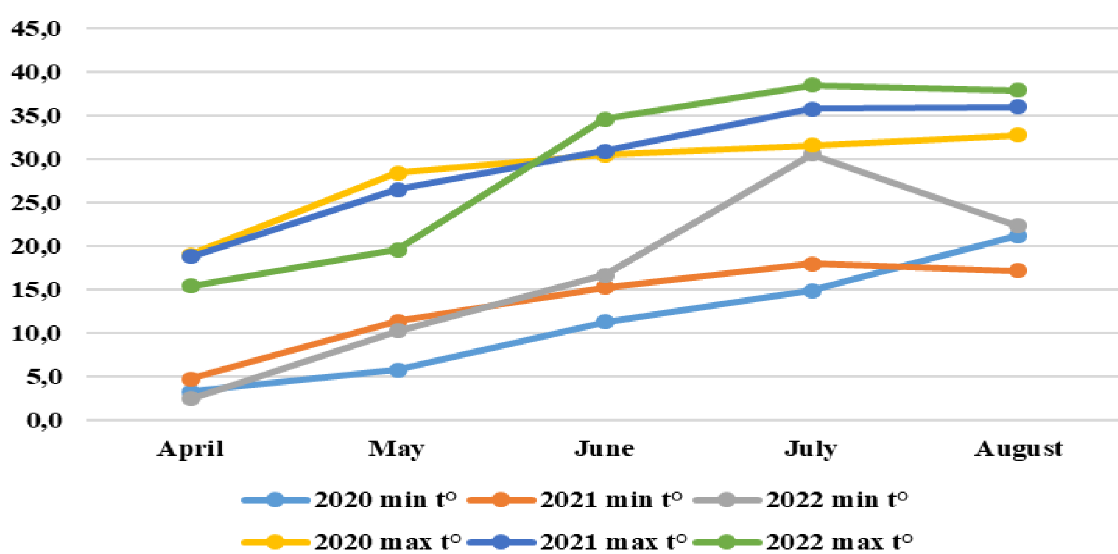


**Figure 1.** Average minimum and maximum air temperature (°C) for the vegetation periods of maize (from April till August) during the three experimental years (2020, 2021 and 2022)

recovery by those plants is the most reasonable explanation for the lower results obtained after applying inter-row hoeing in maize growth stage 10th – 12th true leaf.

The experiment conducted by Silva et al. (2010) reveals that the removal of weeds by hoeing does not reflects on the grain yield. Nevertheless, there is a significant difference between the number of ears in plots that have been hoed and those without weed removal. On Table 2 the data for the ear length is presented. The performing of two inter-row hoeing operations in crop growth stages 3rd – 5th true leaf and 7th – 8th true leaf (variant 3) led to the highest and statistically proven results in comparison to the other treatments – 18.72 cm average for the period of the study. The lowest results were recorded for treatment 4 (Triple inter-row hoeing) – 17.39 cm.

According to Leblanc & Cloutier (2001) hoeing destroys effectively the soil crust which ensures uniformity in the maize development. Many authors suggest that mechanical weed control contributes for the mineralization of soil-bound nitrogen, which may significantly increase the crop yield and quality particularly when the crop requires more nitrogen (Davies & Welsh, 2002; Welsh et al., 2002). Three hoeing operations in maize (15, 30 and 45 days after sowing) was an effective weed control method which provided the highest yields. This was because of the

**Table 1.** Plant height at the end of the vegetation, m.

| Variants / Years | 2020 | 2021 | 2022 | Average for the period |
|---|---|---|---|---|
| 1. Zero inter-row hoeing | 2,32 d | 2,39 c | 2,22 d | 2,31 c |
| 2. Single inter-row hoeing | 2,65 b | 2,51 b | 2,43 b | 2,53 b |
| 3. Double inter-row hoeing | 2,87 a | 2,78 a | 2,66 a | 2,77 a |
| 4. Triple inter-row hoeing | 2,45 c | 2,38 c | 2,34 c | 2,39 c |

*Means with different letters are with proved differences according to Duncan's Multiple Range test ($p < 0.05$).*

**Table 2.** Ear length, cm.

| Variants / Years | 2020 | 2021 | 2022 | Average for the period |
|---|---|---|---|---|
| 1. Zero inter-row hoeing | 17,68 c | 16,87 c | 16,24 c | 16,93 c |
| 2. Single inter-row hoeing | 18,57 b | 17,80 b | 17,45 b | 17,94 b |
| 3. Double inter-row hoeing | 19,33 a | 18,48 a | 18,34 a | 18,72 a |
| 4. Triple inter-row hoeing | 18,27 b | 17,01 c | 16,89 c | 17,39 b |

*Means with different letters are with proved differences according to Duncan's Multiple Range test ($p < 0.05$)*

**Table 3.** Maize grain yield, t ha$^{-1}$.

| Variants / Years | 2020 | 2021 | 2022 | Average for the period |
|---|---|---|---|---|
| 1. Zero inter-row hoeing | 7,75 b | 7,56 b | 7,41 b | 7,57 c |
| 2. Single inter-row hoeing | 7,90 b | 7,71 a | 7,65 a | 7,75 b |
| 3. Double inter-row hoeing | 8,07 a | 7,78 a | 7,69 a | 7,85 c |
| 4. Triple inter-row hoeing | 7,56 b | 7,44 b | 7,32 b | 7,44 c |

*Means with different letters are with proved differences according to Duncan's Multiple Range test ($p < 0.05$)*

considerably reduced density of the weeds which were no longer competitive with the crop (Haseeb Ahmad et al., 2018). On table 3 there are the maize grain yields. The highest statistically proven yields – 7.85 t $ha^{-1}$ at treatment 2 were obtained. In our study, the lowest results were found to be for treatment 4 – 7.44 t $ha^{-1}$.

The parameter absolute seed mass is one of the most important indicators determining crop yields (Georgiev et al., 2014). The absolute seed mass of the maize grains differed among the variants. The highest results were found to be for the treatment where Double inter-row hoeing was accomplished (Treatment 3) – 373.87 g. The results are proved with the other treatments. The lowest results were recorded for the variant with three inter-row hoeing applications – 344.21 g.

The hectoliter seed mass is variety dependable (Vujaković et al., 2014). It differed between the treatments in our experiment. The indicator's values are presented on Table 5. The highest hectoliter seed mass was measured at variant 3 (Double inter-row hoeing) – 76.98 kg. For this parameter the lowest results at variant 4 (Triple inter-row hoeing) were recorded as well – 75.50 kg average for the period of the study.

## CONCLUSION

All studied parameters as plant height, ear length, maize grain yield, absolute and hectoliter seed mass were influenced by the inter-row hoeing performed. The highest results for all studied indicators for variant 3 were obtained where two inter-row hoeing operations were performed.

**Acknoeledgments**

The present research was reported at an jubilee scientific conference with international participation "Sustainable and competitive agriculture under the conditions of global climate change", held in September, 03-04.2024, in Maize Research Institute, Knezha, Bulgaria.

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**Table 4** Absolute seed mass, g.

| Variants / Years | 2020 | 2021 | 2022 | Average for the period |
|---|---|---|---|---|
| 1. Zero inter-row hoeing | 353,57 b | 350,20 b | 345,42 b | 349,73 bc |
| 2. Single inter-row hoeing | 373,21 a | 354,12 b | 347,23 b | 358,19 b |
| 3. Double inter-row hoeing | 379,53 a | 374,58 a | 367,51 a | 373,87 a |
| 4. Triple inter-row hoeing | 352,92 b | 347,57 b | 332,14 c | 344,21 c |

*Means with different letters are with proved differences according to Duncan's Multiple Range test (p < 0.05)*

**Table 5.** Hectoliter seed mass, kg.

| Variants / Years | 2020 | 2021 | 2022 | Average for the period |
|---|---|---|---|---|
| 1. Zero inter-row hoeing | 76,55 c | 75,20 c | 74,90 c | 75,55 c |
| 2. Single inter-row hoeing | 77,10 b | 76,50 b | 75,10 b | 76,23 b |
| 3. Double inter-row hoeing | 77,35 a | 77,10 a | 76,50 a | 76,98 a |
| 4. Triple inter-row hoeing | 76,30 c | 75,40 c | 74,80 c | 75,50 c |

*Means with different letters are with proved differences according to Duncan's Multiple Range test (p < 0.05)*

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*Received:* March, 18, 2025; *Approved:* May, 22, 2025; *Published:* August, 2025